IMPROVED INSULATED DOOR ASSEMBLY
WITH LOW THERMAL DEFLECTION

CROSS-REFERENCE TO RELATED APPLICATIONS

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~~This application~~n is a continuation-in-part of U.S. application Serial

5   No. 08/922,988 filed September 2, 1997, which is incorporated herein by reference.

TECHNICAL FIELD

The present invention pertains to insulated door assemblies having
compression molded skins which exhibit minimal thermal deflection.   More
particularly, the subject invention pertains to insulated door assemblies having skins

10   of compression molded, moderately dark colored, fiber- reinforced sheet molding
compound which exhibit reduced thermal expansion and contraction, which retain
the ability to receive pigmented stains in a uniform manner, and to improved
processes for their preparation.

BACKGROUND ART

15   Entry door system containing fiber reinforced compression molded
door skins are becoming increasingly popular.   An example of the latter is the
Classic-Craft™ door available from Therma-Tru Corporation.   Such entry door
systems contain front and back skins which are generally both prepared from fiber
reinforced sheet molding compound which has been compression molded to provide

20   a wood grain pattern on the door skin.   These door skins are mounted onto stiles and
rails and contain highly efficient thermal insulation between the skins.   Examples of
such door assemblies may be found in U.S. Patents 4,550,540 and 5,537,789.   Such
door entry systems are much more thermally efficient than solid wood doors or
insulated metal doors, as well as being more aesthetically pleasing than the latter.

25   However, the increased thermal efficiency of such doors is a mixed
blessing, often being so effective in reducing thermal transmission from the exterior
to the interior that temperature differentials of 55-60°C may be created between the

exterior and interior skins. In such cases, the skin exposed to the higher temperature will expand to a greater degree than the skin exposed to the lower temperature environment. A portion of this expansive force may be resisted by the adhesive which adheres the skin to the frame; by the frame itself; and by the insulating core.

5 However, stresses on these door components increase dramatically as the temperature differential between opposing skins increases. The stresses can be so great as to temporarily warp the door assembly in a phenomenon known in the industry as "thermal deflection". Consumers, as can be imagined, are generally distraught when they observe this behavior. In addition, the warping or bowing which the door

10 experiences may be of such magnitude that contact between the weatherstripping and door assembly may be lost, thus allowing considerable air infiltration and associated thermal loss.

When thermal deflection occurs, discerning consumers find the products unacceptable in insulated entry door assemblies of even typical residential

15 height, for example, those of about 2 m (6 feet) in height. These doors have lock edges termed "lock stiles" of which the section above the lock may be viewed simplistically as a cantilevered beam approximately 1.1 m in length. Attempts to minimize thermal deflection have been centered on structural changes to the door support members. For example, structural modifications on typical residential

20 insulated door assemblies may use laminated beams in the lock edge or lock stile to reduce thermal deflection. However, the use of such laminated beams results in significant increase in raw material cost. Moreover, such efforts have not been entirely satisfactory, and thermal deflection continues to be a design issue in such products.

25 While thermal deflection has been a considerable problem in entry doors of normal height, when taller doors are used as dictated by recent trends in building products, the problem becomes even more severe. In such taller doors, the lock position remains at a relatively stationary height, i.e., a height convenient for grasping with the hand of the hypothetical "normal" individual. However, the

30 increased height thus requires a considerably longer portion of the door to be located above the lock set. Thus, the combination of increased skin surface area generating

greater force, and a longer cantilevered length, results in a magnitude of thermal deflection which is unacceptable for such doors, even those containing laminated beams in the lock stile.

5   Numerous materials exist which could be substituted for the fiber reinforced sheet molding compound used to make fiber reinforced door skins. Unfortunately, however, the materials of which the door skin is constructed must meet numerous criteria other than merely minimal thermal expansion. For example, the skins must be relatively strong and yet must have appreciable resiliency in order that they may survive the destructive forces generated upon thermal expansion.

10   Further, and more importantly from a commercial aspect, the door skins must be capable of receiving a pigmented stain in a uniform manner, and should also be capable of being economically pigmented to produce a medium dark to dark surface prior to staining and finishing.

15   For example, early "fiberglass" doors were colored white. The white substrate was visible through the thin films of solid color stains used to achieve an appearance of wood. Discerning customers found the substrate color to be unacceptable. Moreover, at locations of the door experiencing wear, the underlying white surfaces are easily exposed, rendering the door aesthetically displeasing. Since about 1984, most manufacturers have pigmented the molding compounds used to

20   compression mold the skins with dark or medium darkness pigments. Thus, the materials of skin construction must be capable of receiving such pigments and also of receiving a stain coating in a uniform manner. Furthermore, the materials of construction must be relatively economical in order that the door systems may be made available at a reasonable price. For these reasons, fiberglass sheet molding

25   compound, consisting predominately of curable unsaturated polyester resins generally incorporating one or more co-curable unsaturated monomers, continue to be used to manufacture textured, compression molded door skins.

       In the preparation of molded articles by the compression molding of unsaturated polyester/co-curable unsaturated monomer compositions, considerable

30   shrinkage results during the molding process due to a volume decrease in the curable

ingredients as these react and crosslink. In non-textured articles, the result may be a cured product which no longer has the dimensions of the mold. In textured articles, the decrease in volume may produce articles with insufficient or indistinct texture. Addition of shrink reducing adjuvants have been found to lower the

5 propensity of the curing polymer system to shrink, thus allowing for full definition of textured surfaces. The efficacy of shrinkage control adjuvants may be assessed by visually observing surface texture, or by measuring the dimensions of cured articles and comparing them to mold dimensions. As the dimensional coefficient of thermal expansion is generally not a linear function of temperature, the expansion

10 and contraction of a cured, finished product over the temperature ranges expected of exterior doors cannot be predicted from measurements made based on compression molding temperatures. Furthermore, those skilled in the art of sheet molding compounds have not been concerned with the thermal expansion of cured, finished products *per se*, only with changes in volume which are the result of curing during

15 the molding process.

Use of sheet molding compound containing low profile additives was disclosed in low linear thermal coefficient expansion moldable materials in Assignee's U.S. Patent 5,537,789,. However, the low profile additive was deemed important to minimize shrinkage of the hot and partially cured skin during molding.

20 There is no recognition apparent from the '789 patent that the low profile additive had any effect on either the linear thermal coefficient of expansion itself or the ability of a door made from compression molded sheet molding compound to resist thermal deflection.

It has been discovered that reduction of the thermal expansion of

25 compression molded door skins prepared from unsaturated polyester sheet molding compounds over the temperature extremes expected during normal use can be accomplished through the use of the same so-called "low profile additives" useful in retaining mold texture definition during compression molding. Low profile additives may be defined as relatively polar thermoplastic polymer materials which, when

30 added to sheet molding compositions, encourage the formation of numerous microvoids. Such additives are believed to phase out during cure under compression

molding conditions, resulting in a multi-phasic polymer system. The phase-out of the low profile additives may increase the volume of the curing mass, offsetting the volume reduction of the curing and crosslinking unsaturated components. Moreover, the different phases appear to exhibit different degrees of contraction upon cooling.

5 As the compression molded skins cool prior to and after their removal from the mold, the different phases contract at different rates, causing numerous microvoids to be created.

The microvoids have been found to aid significantly in reducing the thermal expansion of the finished door skin. Moreover, the microvoids are believed

10 to assist in the creation and propagation of microcracks under stress, which adds to the resilience of the door skins, facilitating their continued adhesion to the door support components. Nevertheless, the use of low profile additives, while decreasing the thermal expansion exhibited by door skins, does not eliminate the expansion altogether. Moreover, when the same sheet molding compounds are used on taller

15 doors, the thermal deflection which results from high temperature differentials is again unacceptably large.

Increasing the amount of low profile additive is effective in reducing the degree of thermal expansion of door skins over normal use temperatures. However, the increase in the number of microvoids creates a porosity problem in the

20 skin surface which manifests itself by a mottled, uneven appearance of a stained skin. This mottled appearance is aesthetically displeasing, and unacceptable to the consumer. Therefore, merely increasing the amount of low profile additive cannot solve the thermal defection problem, as the increased amount of low profile additive cannot solve the thermal deflection problem, as the increased amount of low profile

25 additive creates other problems.

A second means of reducing thermal expansion during compression molding is through the use of shrinkage control additives. While shrinkage control additives have been used in formulating sheet molding compound for use in manufacture of compression molded door skins, use of such additives has been very

30 limited in terms of composition amounts. Such additives were introduced, as is the

case with low profile additives, for minimizing thermal contraction in compression molded materials during cure. It is not known with certainty how shrinkage control additives function. For example, such materials may create a minor volume (quantity) of microvoids, but not nearly the volume associated with the microvoids

5   produced with low profile additives. Moreover, while low profile additives tend to be highly polar polymers, shrinkage control agents tend to be non-polar. For example, common shrinkage control additives are polystyrene, polyethylene, polycaprolactone, and the like, whereas typical low profile additives include polyacrylics such as polymethylmethacrylate, polyvinylacetate, and saturated

10   polyesters having relatively short aliphatic carbon chain lengths.

Entry doors are made in many styles. Currently, many doors which are to have a "paneled" look, i.e., to be structured so as to mimic the traditional rail/stile/panel wood construction, have been produced in the same manner as flat, non-paneled doors. Following production of the flat door, the (traditionally) six

15   panels are introduced by cutting holes in the door following a template, and assembling two-part panels over these holes. The panel halves are secured to each other by screws or press-in plastic fittings, thus "sandwiching" the door between them.

This process of preparing paneled doors has several notable

20   drawbacks. Firstly, the process requires molding of two relatively intricate panel shells, one for each side of the door. The intricate patterns generally require injection molding, and thus the panels will constitute a different material, an injection-moldable thermoplastic, than the sheet molding compound used to prepare the door. Because of the different materials, the stainability of the door and the

25   panels will not be the same. The different color and depth of color due to differences in stainability are immediately noticeable to an observer. Achieving the same color for both parts is time consuming and fraught with error. Secondly, the holes required to be cut to receive the mating halves of the panels severely reduces the strength of the door. Finally, removal of the cut out sections involves removal of the

30   insulating core of the door in these areas as well. Thus, the insulation efficiency decreases markedly.

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The use of SMC materials, particularly those containing the combination of low profile additive and low shrinkage additive as described herein allow the preparation of aesthetically pleasing door skins in a reasonable amount of time. Thus, the overall cost of the door skins is maintained at an affordable level.

5   If the curing of the SMC could be accelerated, increased production rates and further lowered costs would be possible. An increase in curing catalyst level should increase the curing rate. However, increased catalyst loading also increases the propensity for the SMC to prematurely cure. A reasonable shelf life for the SMC therefore precludes merely increasing the catalyst loading.

10   Increasing the amount of catalyst coupled with addition of inhibitors can produce systems which cure at reasonable rates yet offer reasonable shelf life. However, it has been noted that addition of inhibitors also generally reduces the ultimate cure level, i.e. the degree of crosslinking which may be achieved. "Curing percentage" is an indicator of the completeness of the cure. With t-

15   butylperoxybazote catalyst and no inhibitor, for example, typical door skins and other parts exhibit a percentage of cure of about 88-90% at an 85 second demold time. Addition of increased amounts of catalyst along with an inhibitor increases the rate of cure, but the percentage of cure decreases. Suppliers of SMC have proposed the use of catalyst mixtures to speed processing, for example a mixture of t-

20   butylperoxybenzoate and t-butylperoctoate. However, well cured parts retaining uniformly stainable characteristics could not be produced from this catalyst mixture. It would be desirable to provide SMC which has acceptable shelf life; which is faster curing than SMC employing t-butylproxyberzoate curing catalyst; which exhibits similar or better percentage of cure; and which, following cure, is uniformly

25   stainable.

In molding stainable door skins and other parts employing SMC, in general a "stack" of SMC materials of the proper weight is placed into the center of the mold, and the mold closed while heating. The combination of heat and pressure causes the SMC material to flow throughout the mold. Pressure is maintained until

30   cure is effected.

In some cases, blistering and other cosmetic surface defects may be produced during molding. It is known that after the SMC material has flowed to fill the mold, vacuum may be applied. The vacuum tends to reduce surface non-uniformities. Unfortunately, the use of vacuum also produces a "scum" on the surface. This scum is not pigmented to the same degree as is the SMC material, thus presenting a non-uniform surface color. Moreover, the "scum" does not accept stain in the same manner as the SMC material. Thus, the doors cannot be acceptably stained.

It is believed that the "scum" is produced as styrene monomer and low molecular weight oligomers volatilize from the resin and accumulate on the mold surface, where they polymerize. Polymerization inhibitors which may be present are of higher vapor pressure and are left within the matrix, facilitating the polymerization at the surface of the mold due to their absence, as the constituents migrate unevenly. The polymerized scum on the tool surface is scraped off as the SMC material flows in the mold during the pressing operation. The accumulation, which is darkened and discolored relative to the remainder of the SMC is thus distributed unevenly over the molded door skin surface. The loss of styrene monomer and low molecular weight oligomers increases the effective concentration of less volatile inhibitors, resulting in less complete cure of the molded skin.

It would be desirable to provide fiber reinforced insulated door assemblies having fiber-reinforced door skins, preferably textured, and most preferably, wood-grained skins, which can be economically manufactured from sheet molding compound, and yet which exhibit low thermal deflection due to the use of skins having low thermal expansion coefficients. It would further be desirable to provide skins suitable for such door assemblies which are able to be pigmented with medium to dark colored pigments, and which can accept pigmented stains in a uniform manner without the necessity for use of a pre-stain sealer. Such doors have not been heretofore available.

DISCLOSURE OF INVENTION

The present invention pertains to insulated, fiber-reinforced door assemblies, suitable for exterior use, which preferably exhibit minimal thermal deflection, even in doors of greater than normal height. The doors of the present

5   invention contain fiber-reinforced door skins prepared from sheet molding compound which contains a resin system consisting of one or more curable, unsaturated polyester resins, one or more co-curable, unsaturated monomers, a low profile additive, and a microvoid-reducing thermoplastic polymer which is preferably a shrinkage control additive. Surprisingly, the door skins thus produced exhibit not

10   only exceptionally low linear coefficients of expansion, but also are economically pigmentable, and capable of being stained by pigment-bearing stains in a uniform, aesthetically pleasing manner.

It has now been found that paneled doors can be produced simply without cutting holes in the basic door, by using a permanent, pressure sensitive

15   adhesive to bond panels at the appropriate locations. Because the panels are flat and do not contain locating flanges, screw bosses, and the like, they may be made of the same material as the door skin. Thus, stainability mismatches no longer occur. Moreover, both the structural rigidity and insulation value increase, rather than decrease, when employing the adhesively bonded decorative panels. The same

20   adhesives may be used to bond other trim as well. A preferred adhesive is VHB™ Tape available from the 3M Company, which is believed to be an alkylacrylic co-polymer resin.

If has been surprisingly discovered that SMC employing a cure inhibitor in conjunction with a cure catalyst comprising t-amlyperoxybenzoate in

25   major part (>50% by weight based on catalyst) not only allows a significant reduction in cure time (ca.40% reduction in cure time), but importantly, cure percentage is actually higher than non-inhibited t-butylperoxyberzoate systems, at 91-97%! Surprisingly, the skins produced with this inhibitor/catalyst combination are uniformly stainable.

It would be desirable to provide a composition which can be molded under vacuum to reduce surface defects, while retaining stainability. This problem is solved through use of the subject invention SMC employing inhibitor and t-amylperoxybenzoate catalyst. It is believed that the beneficial results achieved are due to the short cure time; i.e. cure times of less than 60 seconds, and preferably less than 50 seconds after mold closure. Thus, other combinations of catalysts and catalyst/inhibitor mixtures which enable cure of a door skin in less than 60 seconds can be used with vacuum in the subject process.

BEST MODE FOR CARRYING OUT THE INVENTION

The fiber-reinforced door assemblies of the present invention include conventional door components such as lock stiles, rails, edges, insulation and the like, and two skins, at least one of which is a pigmented door skin according to the subject invention, this skin prepared from fiber-reinforced sheet molding compound comprising a curable, unsaturated polyester resin, one or more co-curable unsaturated monomers, a pigment, a low profile additive, a microvoid-reducing thermoplastic polymer, preferably of the class known to the art as low shrinkage additives, and fiberglass reinforcement. The sheet molding compound may also comprise fillers, viscosity adjusting agents, dyes, curing catalysts, and other customary ingredients. By the term "a" as used herein with respect to a class of components is meant "one or more". For example, the term "a low profile additive" means that minimally one low profile additive is employed, optionally two or more of such additives. Conventional door components are discussed in U.S. Patents 4,550,540 and 5,537,789, which are herein incorporated by reference.

The curable unsaturated polyester resins are well known to those skilled in the art, and are generally prepared in a non-limiting sense, by esterification or transesterification of one or more unsaturated dicarboxylic acids or reactive derivatives thereof with one or more aliphatic or cycloaliphatic diols. Saturated dicarboxylic acids, aromatic dicarboxylic acids, or their reactive derivatives may be used in conjunction with the unsaturated dicarboxylic acid(s) to lower the crosslink density. Modification of polyester resins by reaction with dicyclopentadiene has

been found to produce preferred curable polyesters for use in accordance with the present invention. Curable polyesters with moderately high to high crosslink density, i.e., a crosslink density lower than that obtainable from poly(ethylenemaleate) can produce skins with high resilience while maintaining

5   strength characteristics. Curable polyester resins are available commercially, and are disclosed in U.S. Patents 3,969,560; 4,172,059; 4,491,642; and 4,626,570, which are herein incorporated by reference.

The co-curable unsaturated monomers are also well known to those skilled in the art, and include, for example, the various alkylacrylates and

10   alkylmethacrylates as well as vinyltoluene α-methylstyrene, p-methylstyrene, and styrene, the latter being preferred. By the term "co-curing" is meant that the monomer contains reactive unsaturation capable of reacting with itself and/or the unsaturated sites of the curable polyester under the curing conditions. Additional co-curable monomers are identified in the above-referenced patents. A preferred

15   curable unsaturated polyester/co-curable unsaturated monomer combination is a dicyclopentadiene-modified glycol maleate polyester and styrene monomer composition available from Alpha/Owens Corning under the product designation S-903.

Low profile additives are well known to those skilled in the sheet

20   molding composition art. Low profile additives are generally relatively polar thermoplastic polymers such as polymethylmethacrylate, polyvinylacetate, various poly(alkyl)acrylate polymers and copolymers, and saturated polyesters, particularly those having a diol component of low molecular weight, such as ethylene glycol or diethylene glycol, i.e., a glycol having 2-4 carbons, optionally interspersed with

25   ether linkages in the hydrocarbon chain. Low profile additives are generally recognized as creating microvoids in the cured product. While the mechanism of microvoid formation is not known with certainty, it is believed that during the cure of the curable polyester and co-curable monomer to form a thermoset structure, a microgel phase is formed from the curing/crosslinking of the unsaturated components

30   which is at least partially incompatible with the low profile additive, which begins to phase-separate. The phase separation causes an increase in volume of the

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composition which partially or wholly offsets the shrinkage which results from curing of the polyester/co-curable monomer. The curing polyester forms a matrix which at least partially surrounds the low profile additive phase. Upon cooling, the differences in volume contraction between the two phases results in the formation of

5   microvoids. The presence of such microvoids may be observed by microscopic inspection of the surface, and by the porosity which portions of the surface exhibit with respect to absorbance of liquids, which otherwise would be minimal. More than one low profile additive may be used.

It has been unexpectedly discovered that the low profile additives are

10   more effective if the molding pressure is reduced by 10-50% after the resin has gelled. Benefits of the technique are either more low profile additive effect, use of lower amounts of low profile additive to achieve the same result, or both these benefits.

The sheet molding compositions also contain a microvoid-reducing

15   thermoplastic polymer. By the term "microvoid-reducing" is meant the reduction of microvoids on at least one surface of the compression molded door skin. The reduction of microvoids may be assessed by comparing the mineral spirits uptake of a compression molded product with an otherwise similar product prepared from a composition which does not contain the microvoid-reducing thermoplastic polymer.

20   A suitable microvoid-reducing thermoplastic polymer is one which causes a measurable reduction in the mineral spirits uptake under such circumstances. A variety of polymers are suitable for use as microvoid-reducing thermoplastic polymers, including polystyrene, polyethylene, copolymers of styrene and acrylonitrile, and aliphatic polyamides formed from longer carbon chain length

25   monomers, and the like. In general, microvoid-reducing thermoplastic polymers tend to be non-polar polymers. Preferred microvoid-reducing thermoplastic polymers belong to the general class of sheet molding compound additives known as low shrinkage additives. More than one microvoid-reducing polymer may be used.

Low shrinkage additives are well known to those skilled in the art, and

30   by contrast to low profile additives, have substantially less effect on microvoid

formation. As with low profile additives, phase out during cure creates a multiphasic system. However, upon cooling, microvoid formation does not occur to a substantial extent. Rather the volume expansion which occurs during phase out contributes to maintenance of volume during the molding operation. Unlike low profile additives,

5   low shrinkage additives are non-polar, or of relatively low polarity. Non-limiting examples include polyethylene, polystyrene, polyolefins in general, such as ethylene copolymers with other monomers such as hexene and octene, cyclohexene, and the like, polypropylene and polypropylene copolymers, and saturated polyesters having appreciable methylene chain lengths such as polycaprolactone. Polystyrene and

10   polyethylene are preferred. Toughened polymers such as high impact polystyrene, and various modifications of the above polymers such as high density linear polyethylene, isotactic and atactic polypropylene and the like are suitable. More than one low shrinkage additive may be used.

In choosing a microvoid-reducing thermoplastic polymer in a

15   formulation, the formulator must consider the compatibility of the skin pigments and stain pigments with the microvoid-reducing thermoplastic polymer. For example, when using iron oxide pigments, best performance in stain pigment adhesion occurs when the microvoid-reducing thermoplastic polymer has a relatively high surface energy. For example, with polyolefins in particular, low pigment/microvoid-

20   reducing thermoplastic polymer compatibility occurs with polyolefins having a low surface energy, such as homopolymeric polyethylene. Thus, with polyolefins, a surface energy above 38 mJ/m^3, preferably above 40 mJ/m^3 is preferred. These surface energies are preferred for non-olefin polymers as well. Acceptable adhesion, 4 or 5B, measured in accordance with ASTM-3359 after allowing time for full cure

25   (ca. 7 days), decreases rapidly as surface energy decreases. The quantity of microvoid-reducing thermoplastic polymer must be reduced accordingly. At a point, the uniformity of staining ceases to be acceptable to the consumer, despite acceptable adhesion. A surface energy below 36 mJ/m^3 is generally unacceptable. Blends of polymers having high and low surface energies may be used in certain instances.

30   Suitable pigments are preferably those which result in a medium to dark pigmented skin, for example skins having an L* value between 66-75 units,

preferably 66-71 units, measured in accordance with the 0-100 CIELAB Opponent Color Scale of test method SAE J1545 color analysis at a reflectance of 45° and an observer angle of 2° with D65 illumination. A variety of natural and synthetic pigments, both organic and inorganic are suitable, inorganic pigments generally being preferred from a light stability viewpoint. Suitable pigments are, for example, the various iron oxide pigments and carbon black. Iron oxide pigments are commercially available in colors ranging from black through brown and red to yellow. Mixtures of various pigments, including lighter pigments such as titanium dioxide, may be used to create a variety of light to dark brown and brown-red tones to simulate woods such as cherry, oak, walnut, and mahogany. The pigments are generally supplied to the molding formulation as a pigment grind in a suitable grind vehicle, for example a minor amount of liquid polyester. Pigments are generally employed in amounts of up to 20 weight percent, more preferably 1 weight percent to 15 weight percent, and more preferably about 2 weight percent to 10 weight percent, these weight percentages based on the total weight of all non-fiberglass and non-filler composition components.

The sheet molding composition generally contains a catalyst in an amount effective to cure the sheet molding compound in a reasonable time. Such catalysts are heat activatable, and are well known, including azo compounds such as azobis-(isobutyryronitrile) (AIBN), peroxides, hydroperoxides, peroxyesters, peroxyketones, and the like. Such catalysts generally cure the curable polyester by a free radical mechanism, and may be broadly termed free radical polymerization initiators. Catalysts which are effective in the typical compression molding temperature range of 100°C to 200°C, preferably about 150°C, are preferred.

Plasticizers may be used in the subject compositions where necessary. Preferably, plasticizers used will have a low vapor pressure and/or exhibit suitable solubility in system components such that the plasticizers will be substantially non-fugitive, i.e., will remain in the door skins even when subjected to relatively high temperatures as might be experienced by the exterior of a door exposed to sunlight through a glass storm door. Examples of suitable plasticizers include the various phosphate esters such as tricresylphosphate, low molecular weight polyester

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oligomers, and the like. Reactive plasticizers, for example, oligomeric saturated polyesters bearing a terminal or pendant site of unsaturation may be used as well.

Viscosity modifiers may also be used. Viscosity modifiers may include a number of ionic and non-ionic surfactants, associative thickeners, high

5 molecular weight polyacrylic acid and polyacrylic acid copolymers, and the like. Such adjuvants are generally used in quantities of less than 5 weight percent, preferably less than 2 weight percent, and most preferably about 1 weight percent or less, these weight percents relative to the resin system component weight. Viscosity modifiers may increase or decrease viscosity as desired, or may introduce thixotropy

10 into the composition.

Fillers are generally used in the subject invention. The amount of filler may range from 0 weight percent (no filler) to substantially in excess of 50% based on the non-fiberglass components. Amounts up to 75 weight percent have been found suitable, for example. Suitable fillers include various metallic oxides,

15 hydroxides, carbonates, and the like. Suitable fillers also include various natural minerals including clays and finely ground limestone.

Fiberglass reinforcement or other fibrous reinforcement is necessary. While carbon fibers are currently too expensive to be commercially viable, such fibers are also well suited to the door skins of the present invention. By the term

20 "fibrous reinforcement" is meant inorganic or organic reinforcing fibers which maintain their integrity at temperatures of at least 200°C and which are substantially non-soluble and non-swellable in the polyester sheet molding composition. Preferably, glass, carbon, or ceramic fibers or their mixtures are used. The fibers may be chopped (staple) fibers, continuous fibers, or mixtures of chopped and

25 continuous fibers. Glass mat fibers such as are produced by needling or felting continuous fibers and/or staple fibers may be used as well.

A portion of the fiberglass may be substituted by mineral fillers without loss of significant physical properties. For example, it has been surprisingly discovered that up to about 25% or more of the fiberglass can be substituted by

wollastonite, preferably up to 15%. When fillers such as wollastonite are used, they are added to the A-side curing resin system instead of separately and later as chopped fiberglass.

5   By the term "curable resin component" is meant the total of curable unsaturated polyester(s) and co-curable unsaturated monomer(s). By the term "resin system" is meant the total of the curable resin component, low profile additive, and microvoid-reducing thermoplastic polymer. The term "major" as used herein means 50% or more on a weight basis. The term "minor" as used herein means less than 50% on a weight basis.

10   Having generally described this invention, a further understanding can be obtained by reference to certain specific examples which are provided herein for purposes of illustration only and are not intended to be limiting unless otherwise specified.

Comparative Example 1

15   A series of test doors are constructed with compression molded, wood-grained skins of curable polyester sheet molding compound, containing 22-25 weight percent E-glass fiberglass reinforcement and polystyrene as a low shrinkage additive. The sheet molding composition is pigmented to produce a dark wood-tone skin. The sheet molding compound, when cured, has a linear coefficient of thermal
20   expansion of about $21.6\text{-}23.4 \times 10^{-6}$ mm/mm/°C. Two series of doors are made from similar materials, the first series having a cantilevered length above the lockset of 1120 mm, the second series having a cantilevered length of 1525 mm.

Thermal deflection of the series of doors is measured by inserting each door into an aluminum frame, the door constrained with clamps at four points, the
25   first three simulating the three hinge points, the fourth simulating the lock point. The temperature of the outside surface of the door is increased by exposure to a bank of infrared lamps until a temperature differential of 56°C is established between the exterior and interior sides of the door, this differential generally being established

in a time period of about 2 minutes. Pinpoint dial indicators are placed at several locations. The deflection measured by a dial indicator mounted at the distal end of the longest cantilevered section, i.e., the top lock-side corner, is the "thermal deflection value". Maximum deflection is measured over a 6-10 minute period of

5   infrared exposure. The nominal six foot doors (1.12 m cantilevered length) are found to have a thermal deflection of 6.4 - 10.2 mm. The normal 8 foot doors (1.525 m cantilevered length) are found to have a thermal deflection of 18-19 mm, i.e., almost one inch (25.4 mm). The thermal deflection values of these doors are marginally acceptable for six foot doors, and unacceptable in the eight foot doors.

10   The door skins have a good color and stain acceptably without undue mottling.

Comparative Example 2

An eight foot door having a cantilevered length above the lockset of 1.525 m is prepared from a darkly pigmented fiber reinforced sheet molding compound as in Comparative Example 1, but with the resin system modified to

15   reduce the linear coefficient of thermal expansion to a value of 10.0×10^{-6} mm/mm/°C. The resin system contains an orthophthalic acid-modified poly(propylene maleate) unsaturated polyester, styrene comonomer, and a large amount of polyvinylacetate low profile additive. The door exhibited an acceptable thermal deflection of only 3.3 mm. However, the microvoid density is so great that

20   the pigmented skin color appears whitened by 10 L^* units to a medium wood-tone color having an L^* value of 71. Although this color tone may be acceptable to the consumer, it is less darkly pigmented than desired based on the pigment loading. A darker door would require a higher amount of relatively expensive pigment. More importantly, the door skins exhibit a noticeable mottled appearance when stained,

25   which is aesthetically unacceptable. Application of a seal coat prior to staining substantially eliminates or minimizes mottling. However, use of a separate seal coat during finishing by the consumer is commercially unacceptable.

The above comparative examples indicate that decreasing the linear coefficient of expansion of the door skins significantly decreases the thermal

30   deflection exhibited by doors having these door skins mounted thereon. The

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coefficient of linear thermal expansion (CLTE) of door skins in accordance with the subject invention should be less than 17.8×10^{-6} mm/mm/°C, and preferably in the range of $0\text{-}13 \times 10^{-6}$ mm/mm/°C, both within the temperature range of -40°C to 95°C. However, these examples further indicate that merely decreasing the CLTE

5   by adding additional low profile additive results in a door with unacceptable aesthetics: a door with less than the desired color saturation, and one which presents a mottled appearance upon staining. Both these effects are believed due to the presence of the large amount of microvoids produced by the large amount of low profile additive required.

10   The ability of a compression molded door skin surface to accept stain has been found to correlate with the uptake of mineral spirits by the door skin material. A suitable test method consists of preparing 60 mm x 25 mm x 3 mm plaques of compression molded skin. The molded sample is weighed, then immersed for 60 seconds in mineral spirits. The sample is removed and the outside surfaces

15   hand wiped with a laboratory towel to remove excess mineral spirits. The sample is weighed after 5 minutes. The increase in weight reflects the mineral spirit uptake. When expressed in weight percent, it has been found that "mineral spirit uptake" of less than 0.15%, and preferably in the range 0-0.05% provides a surface which can be stained uniformly with consumer acceptable aesthetics. Mineral spirit uptake of

20   0.15% and higher produce stained surfaces of mottled appearance which are unacceptable to the consumer. The mottled nature of such surfaces may be easily discerned, without visual aids, by the casual observer.

It has now been surprisingly discovered that the concurrent use of both a low profile additive and a microvoid-reducing thermoplastic polymer, preferably a low shrinkage additive, in fiber-reinforced sheet molding compound compositions

25   enable the manufacture of doors having minimal thermal deflection while at the same time providing for good color tone and surface characteristics which allow for uniform staining. The door skins are economical in their use of pigment, and do not require a pre-stain sealing step. In a preferred embodiment, the skins are prepared

30   in a mold having a temperature differential of preferably at least 3°C between the mold surface which abuts the internal face of the door skin and the mold surface

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which abuts the external skin face. By the term "external" is meant the door skin surface which will be exposed in the door assembly.

The resin system of the present invention comprises a curable unsaturated polyester resin co-curable monomer admixture in an amount of from about 40-80%, preferably 50-70%; a low profile additive in an amount of from about 15-40%, preferably 15-35%, and more preferably 20-30%; and a microvoid-reducing thermoplastic polymer, preferably a low shrinkage additive in an amount of from about 5-30%, preferably 10-25%, and most preferably about 10-20%, all these percents being percents by weight relative to the total resin system of the above-identified ingredients. The amounts of curable unsaturated polyester and co-curable unsaturated monomer are within the conventional ranges for sheet molding compounds.

In addition to the resin system, the sheet molding compound also preferably contains, in parts per 100 parts resin system, from 1 to about 20 parts pigment, preferably 2 to 10 parts, and most preferably 3 to 8 parts; from 0 to 5 parts, preferably 0 to 2 parts, and most preferably about 1 part viscosity adjuster; from 0.01 to 5 parts, preferably 0.1 to 2 parts, and more preferably 0.5 to 2 parts cure catalyst; 0.01 to 5 parts, preferably 0.1 to 2 parts, and more preferably 0.5 to 2 parts of cure catalyst inhibitor to impede room temperature cure, thus prolonging shelf life of the uncured sheet molding compound; 0-250 parts, preferably 30-250 parts, and more preferably 100-200 parts, most preferably about 150-190 parts mineral filler; a pigment grinding vehicle, supplied along with pigment, and present in the composition in amounts of from 0.1 to 10 parts, preferably 0.5 to 5 parts, and most preferably 0.5 to 2 parts; and optionally other customary ingredients. Fibrous reinforcement is present, preferably as chopped E-glass fibers having nominal 25 mm length, in amounts of 65 parts to 300 parts, preferably 70-200 parts, and most preferably 75-110 parts.

In the aspect of the present invention directed to improved cure time, the amounts of catalyst and inhibitor set forth in the prior paragraph should be adjusted. In particular, when using t-amylperoxybenzoate as the catalyst, total

catalyst should be minimally about 0.5 parts catalyst per 100 parts molding resin, to a maximum of preferably about 5 parts per 100 parts molding resin. Lesser amounts than 0.5 pph will be expected to produce only partial cure. Larger amounts then 5 pph may be occasionally useful, for example where SMC is used directly after

5   manufacture, or when large amounts of inhibitor can be tolerated. However, amounts greater than 5 pph are not desirable. Preferably, the amount of t-amylperoxybenzoate-containing catalyst will range from 0.8 pph to 2.0 pph.

The inhibitors discussed in the preceding paragraphs are generally supplied in the form of a solution in order that they may be uniformly incorporated

10   into the resin. The solutions generally contain about 5% solids (inhibitor). The amount of inhibitor previously discussed is based on parts per hundred parts resin of the inhibitor solution. In terms of neat inhibitor (generally a solid), the amount of inhibitors useful with the preferred t-amylperoxybenzoate catalyst ranges from 0.0005 to about 0.05 pph, again based on resin. Irrespective of these amounts, the

15   amount of inhibitor should be that which is effective to provide for the desired storage period and full flow under molding conditions, yet not be so high as to substantially interfere with full cure. Thus, the "effective amount" of an inhibitor may vary somewhat depending upon the nature of the curable composition (resin) and the amount and nature of cure catalyst.

20   Cure percentage is measured by industry standard methods. In one such method, a weighed sample is sealed within a crimped aluminum pan and subjected to cure at a set temperature in a Differential Scanning Calorimeter. Methods for percentage cure may also be found in the literature.

The sheet molding compositions are prepared by standard preparation

25   techniques. Low profile additives, microvoid-reducing thermoplastic, and other ingredients where desired, may be dissolved in co-curable unsaturated monomer, e.g., styrene and added in this fashion. In general, the non-fiberglass components are well blended, for example, in high shear, single shaft mixer, a rotating horizontal shaft plow blade mixer, a double planetary mixer, the latter being preferred, or the

30   like, following which the glass fibers are added. The composition is pumped or

otherwise processed onto a release film, fiber reinforcement is applied over the initial layer, and a second sheet molding composition applied over the fiberglass reinforcing layer. The layered composition is compressed or worked with rollers to a degree sufficient to wet out the fiber reinforcement and produce a unitary, fiber-reinforced

5   sheet molding compound. Details of the preparation of such products is well known to the skilled artisan. The present invention is not limited to sheet molding compound produced by the above process, but applies generally to sheet molding compound suitable for manufacture of compression molded door skins, and containing unsaturated polyester, co-curable unsaturated monomer, low profile

10   additive, and microvoid-reducing additive, regardless of the actual method of preparation. The finished product is optionally covered with an additional release film or foil.

To prepare a fiber reinforced, pigmented door skin, a suitable mold, preferably a male/female mold having a wood grain pattern with undercuts on the

15   mold surface which will form the external skin surface ("exterior surface" or "textured surface"), as described in U.S. Patent 5,537,789, is heated to about 150°C, sheet molding compound inserted, and the mold closed under pressure (200 psig to 1500 psig generally, preferably 800-1200 psig) for a period of about 2 minutes. A cured or partially cured door skin is then removed. In the case of partially cured

20   skins, an oven post cure may be required.

During the molding process, without wishing to be bound to any particular theory, it is believed that during the various phase-outs which occur during crosslinking/curing of the curable polyester/co-curable monomer, the low profile additive forms a phase separate from that of the microvoid-reducing polymer or low

25   shrinkage additive. The microvoid-reducing polymer or low shrinkage additive phase migrates to the skin surface. Upon cooling, the low profile additive generates microvoids, as expected. However, the low shrinkage additive-rich zone near the surface prohibits or substantially minimizes surface microvoids. As a result of the diminished number of microvoids at the surface, uniform stainability is achieved.

30   At the same time, the combination of lack of surface microvoids, together with what

is believed to be greater compatibility of the pigment with the low profile additive, enhances the color saturation, making more efficient use of pigment loading.

The present inventor has further discovered that by compression molding the door skins in a press wherein the temperature of the mold surface abutting the external surface of the skin ("textured mold surface") is maintained at a temperature higher than the temperature of the mold adjacent the internal skin surface, the stainability of the textured skin is markedly improved. This effect is believed due to a preferential migration of low shrinkage additive toward the warmer side of the mold. The temperature differential is preferably at least 3°C, more preferably about 3°C to 20°C, and most preferably in the range of 3°C to 10°C.

The term "door components" as used herein is inclusive of molded components useful in composite doors, including but not limited to doorskins, doorlites, doorlite plugs, door jambs, brickmold, pilasters, rails, stiles, and other millwork "veneers" or facings.

Example 1 and Comparative Example 3

Two otherwise identical 8 foot doors were prepared, using, in Comparative Example 3, the resin system of Comparative Example 1, and using, for Example 1, a sheet molding composition containing the following ingredients:

INGREDIENT	PARTS BY WEIGHT
Curable polyester/co-curable monomer[1]	60
Low profile additive[2]	25
Shrinkage control agent[3]	15
Iron/oxide/titanium dioxide pigment[4]	6
Grinding vehicle adjuvant[5]	1
Mold release adjuvant[6]	4
Viscosity adjusting adjuvant[7]	1
Mineral filler adjuvant[8]	180
Cure catalyst[9]	1
Inhibitor[10]	0.3
Chopped (25.4 mm) E-glass fiber	94
Thickener[11]	1

[1] Alpha/Owens-Corning E-903-1, DCPD-modified glycol maleate polyester and styrene

[2] Alpha Owens-Corning E-4300-1, diethylene glycol adipate polyester dissolved in styrene

[3] Alpha/Owens-Corning P-714, polystyrene dissolved in styrene

[4] Plasticolor CM-44784

[5] Ashland MR 1208A

[6] Norac Coad 10

[7] Vinyltoulene

[8] Huber 10-4

[9] t-butylperbenzoate

[10] Ashland Mod - E

[11] Plasticolor PG-9033

Example 2

The composition of Example 1 is employed to produce a door skin in the same manner as the door skin product from the Example 1 composition. However, the Example 1 composition is modified by replacing the t-butylperoxybenzoate catalyst, used at about 1.5 parts per 100 parts resin, (1 part/60 parts resin) with the same amount of t-amylperoxybenzoate, with 0.2 parts p-benzoquinone inhibitor. Cure time of the t-amylperoxybenzoate-catalyzed SMC is 45 seconds and results in a cure percentage of 91-97%, as compared to a cure time of 85 seconds and a cure percentage of 88-89% for the composition of Example 1.

Comparative Example 4

Example 2 is repeated, but a mixture (1:1) of t-butylperoxybenzoate and t-butylperoxy-2-ethylhexanoate is employed as a catalyst. The door skin produced is not well cured and does not stain uniformly.

Comparative Example 5

A vacuum assisted molding is prepared using the composition of claim 1. To prepare the molding, a 450-550 g/ft^2 charge of material in 2-4 layers occupying 15-30% of the tool surface is positioned near the center of the mold, preferably in the center of "full panel tools" having a single surface unbroken by doorlite openings. On "open panel tools", i.e., ones having openings for doorlites, either flush-glazed style where glass is inserted during assembly, or rimmed hole style where the edges of the interior surfaces mate and glass is inserted as a doorlite after assembly, multiple charges are often used. The mold is closed with the mold surface temperature being 150°C (range 100°C to 200°C), and with the textured (wood-grained) surface maintained at 3-20°C, preferably 3-10°C higher than the non-aesthetic surface. Closure rate of the mold is 8-10 in/min (preferable range: 6-14 in/min, more preferably 8-12 in/min). When the 8" wide vacuum shirt makes sealing contact with the lower portion of the mold, a vacuum of 20-22 inches mercury (general range, 10-29 in Hg; preferable range: 15-25 in Hg). Mold closure is

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completed, with mold pressure of 800-1200 psig (preferable range 200-1500 psig). The vacuum is released 10-23 seconds after mold closure. Composition pressure is released after 85 seconds. The finished part contains a "scum" surface on the aesthetic side which dues not uniformly accept stain.

5

Example 6

Comparative Example 5 is repeated but employing the composition of Example 2. Cure time (comparison pressure release) is 45 seconds. The part exhibits a uniform appearance and is uniformly stainable.

Conventional molding techniques were employed, with a nominal mold
10 temperature of 150°C, the textured (wood grained) surface of the mold maintained at a 3-10°C higher temperature than the other mold surfaces. Molding pressure was 1000 psig.

Having now fully described the invention, it will be apparent to one
15 of ordinary skill in the art that many changes and modifications can be made thereto without departing from the spirit or scope of the invention as set forth herein.

While embodiments of the invention have been illustrated and described, it is not intended that these embodiments illustrate and describe all possible forms of the invention. Rather, the words used in the specification are
20 words of description rather than limitation, and it is understood that various changes may be made without departing from the spirit and scope of the invention.